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Growth Of White Fir After Douglas-Fir Tussock Moth Outbreaks: Long-Term Records in the Sierra Nevada

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Abstract

Radial growth of white fir trees, *Abies concolor* (Gord. and Glend.) Lindl. ex Hildebr., defoliated almost 30 years ago by Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), in the central Sierra Nevada was compared with 22 years of growth prior to the outbreak. There was little difference in growth between the two periods indicating that enhanced growth of defoliated trees after the outbreak did not occur as reported for two other California outbreaks. Increment cores also revealed for the first time an even older outbreak, which occurred on the same site in 1906-8.

Keywords: Increment (radial), insect outbreaks, Douglas-fir tussock moth, white fir, California (Sierra Nevada), Sierra Nevada—California.

Introduction

The long-term effects of a Douglas-fir tussock moth (DFTM) outbreak on growth of white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) in California were recently reported (Wickman 1980). This type of information is rare because tree and stand records from past outbreaks are practically nonexistent. Forest management activities have also drastically altered most old outbreak areas. One old outbreak near Mammoth Lakes in the Inyo National Forest, California, was relocated and sampled in 1977. Growth measurements taken of severely defoliated trees on a study plot established in 1938 indicated that radial growth of white fir was greatly enhanced for 36 years after the outbreak collapsed. Growth of defoliated trees was significantly greater than growth of nearby nondefoliated hosts during the entire postoutbreak period, although preoutbreak growth was similar for both stands (Wickman 1980). This outbreak suffered 30 percent tree mortality on the study plot, and increased growth rate of survivors was attributed to increased availability of water, nutrients, and sunlight. In other words, the tree mortality had a thinning effect that proved beneficial to survivors. Similar responses after DFTM defoliation were noted in white fir 10 years after an outbreak in northeastern California (Wickman 1978a). Questions often posed are does this accelerated growth compensate for growth loss and perhaps some of the mortality during an outbreak? and is this a common stand response after severe DFTM outbreaks? Both questions are difficult to answer because of the paucity of records on old outbreaks and the changes imposed on many of these areas by human activities during the intervening years. My approach to this problem is to reexamine old outbreak sites where tree defoliation and stand damage information are available. Then I use these sites for case studies by using dendrochronological techniques to reconstruct preoutbreak and postoutbreak growth rates as related to defoliation history.

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There are currently only three old outbreak areas in California that have defoliation and tree damage records. The two already mentioned are still being measured periodically. A third area is located on the west slope of the central Sierra Nevada in the Stanislaus National Forest. This outbreak occurred in 1954-56 and tree damage was studied on permanent plots for 5 years after the outbreak was treated with DDT (Wickman 1963). In the most severely defoliated stands at Hell's Mountain, white fir mortality amounted to 20 percent of the stand volume, and radial growth reductions from 1955 to 1957 averaged 74 percent.

A remeasurement of plot trees on this severely damaged area was scheduled for 1981 to record 22-year postoutbreak growth response. Unfortunately, in 1976 a large, intense forest fire burned from Cherry Valley northward through the plots. The fireline extended through or adjacent to the entire 1956 study area and very few study trees survived the fire or subsequent salvage logging. Increment cores taken during a reconnaissance of the area in June 1980 showed depressed growth patterns in 1956 and 1957 in trees immediately east of the fireline and the old study area. This, combined with mapped defoliation, indicates that tussock moth defoliation extended into the adjacent stand. In September 1981, trees in the old Hell's Mountain DFTM outbreak area were sampled for radial growth. This paper reports the 22-year postoutbreak growth patterns found in the area and records for the first time an even older outbreak that occurred in the same area.

Study Site and Methods

The study site is about 19.3 km east of Long Barn, California, in the Stanislaus National Forest. Elevation varies from 1951 to 2073 m. The original mixed conifer stand was composed of about 75 percent white fir, 15 percent red fir (*Abies magnifica* A. Murr.), 5 percent Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), and 5 percent sugar pine (*Pinus lambertiana* Dougl.). Green stand volume of true fir prior to the outbreak was 133,380 board feet per ha. Pine volume was not recorded because the stand was logged for old-growth pine in 1955. Many old-growth fir were killed by secondary insects after the DFTM infestation. Five years after severe defoliation 27,170 board feet per ha had been killed (Wickman 1963). Defoliation was mapped as heavy throughout the Hell's Mountain area in 1956,[1] but heaviest defoliation was patchy and was located mostly on the ridgetop; individual tree defoliation estimates were made only on the study plots that were later burned.

Twenty white fir, which by evidence from growth patterns and mapping were defoliated in 1956, were cored at breast height adjacent to the fireline on an east-west transect approximately 400 m long near the ridgetop. The aim was to duplicate the layout of the old 1956 plots, but at a location 45-60 m north of the fireline.

[1]Mimeographed report, 1957, "Control of an Infestation of the Douglas-Fir Tussock Moth With DDT Aerial Spray: Calaveras and Tuolumne Counties, California," by R.E. Stevens, U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station. Report on file, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701.

There were no known comparable fir stands nearby that escaped defoliation in 1955-56. An area that suffered light defoliation in 1956 was located instead at Jawbone Pass 800 m west at 1951 m elevation. This area had about 10 percent more white fir in the stand and very little red fir, but basal area (based on a 16-point sample) and stand age were similar to the heavily defoliated plot. There was no tree mortality due to defoliation in this area and, consequently, no "thinning effect" was expected in this stand.

Dominant and codominant sample trees were selected from each of three classes as follows: 20 heavily defoliated white fir, 10 nonhost pine in the same area, and 10 lightly defoliated white fir nearby. A tabulation of diameter and age distributions for each tree class follows:

	Heavy defoliation (*n* = 20)	*Nonhost (pine)* (*n* = 10)	*Light defoliation* (*n* = 10)
Diameter (in centimeters):			
$\bar{x}$	60.96	60.96	76.2
range	33-109.2	45.7-114.3	38.1-111.8
Age (in years):			
$\bar{x}$	99	103	107
range	61-235	69-230	70-164

Two increment cores were taken from each tree at breast height, 90 degrees from each other (usually from the north and west quadrants), and to the center of the tree. Cores were mounted on wood blocks and measured on a Bannister incremental measuring machine that was interfaced with an Apple-II desktop computer for recording, tabulating, and exhibiting data.[2] Annual measurements on cores were averaged for each tree class and 22-year preoutbreak rates were compared with 22-year postoutbreak growth rates.

[2]Use of a trade name does not imply endorsement or approval of any product by the USDA Forest Service to the exclusion of others that may be suitable.

Results and Discussion

Average annual preoutbreak and postoutbreak growth rates did not differ for any of the three classes (table 1). Lightly defoliated trees were faster growing than the other two classes from immediately after the outbreak until 1973 when all three classes were growing at about the same rate. This growth pattern continued through 1981 (fig. 1). These results are different from those reported for the Mammoth Lakes site 36 years after an outbreak. There, 36 years of postoutbreak growth of defoliated trees was significantly greater than 36 years of postoutbreak growth of nearby nondefoliated hosts (Wickman 1980). This enhanced growth of defoliated fir probably compensated for individual tree growth lost during the 5-year outbreak and immediate postoutbreak period at Mammoth Lakes.

Table 1—Average white fir and pine growth before, during, and after a Douglas-fir tussock moth outbreak, Stanislaus National Forest

			Radial increment in mm per year	
Period	Years	Tree class	$\bar{x}$	±S.E.
1933-54	22	H.D. 1/	3.018	± 0.09
		L.D. 2/	3.665	± 0.10
		Pine	2.703	± 0.06
1955-59 (DFTM effects)	5	H.D.	1.478	± 0.32
		L.D.	2.758	± 0.44
		Pine	2.208	± 0.18
1960-81	22	H.D.	2.977	± 0.10
		L.D.	3.625	± 0.18
		Pine	2.823	± 0.07

1/ H.D. = heavy defoliation

2/ L.D. = light defoliation

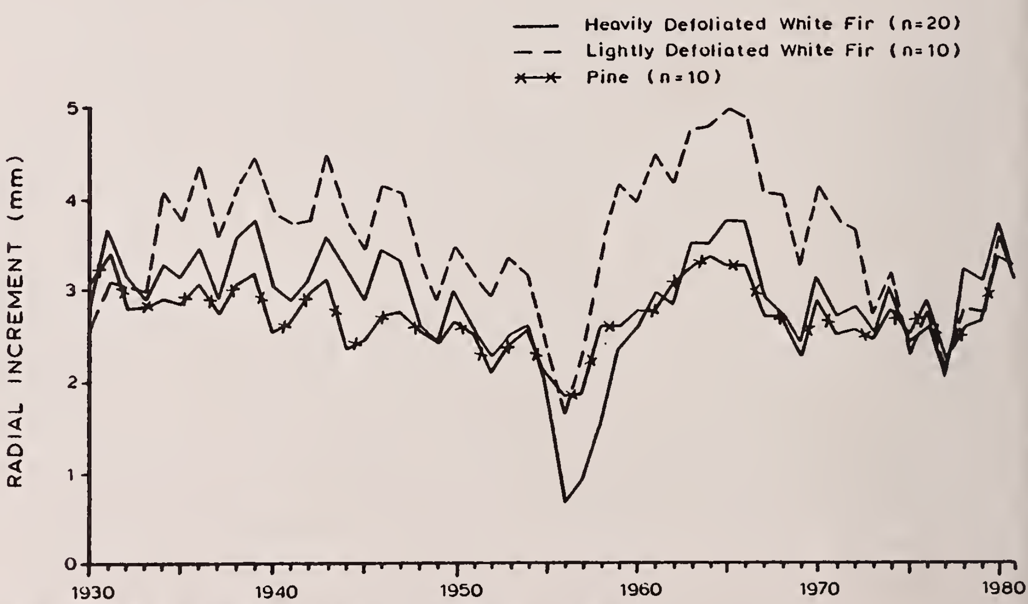

Figure 1.—Average annual radial growth of white fir and pine at Hell's Mountain Douglas-fir tussock outbreak area, 1930 to 1981.

There was no similar pattern of postoutbreak accelerated growth at Hell's Mountain for heavily defoliated trees, but lightly defoliated trees did exhibit a 7-year period of enhanced growth following the outbreak. There was also no increased pine growth during the first 20-year postoutbreak period as noted at Mammoth Lakes (Wickman 1980).

These results are important because they indicate that a "thinning effect" may not occur on all sites and stands after severe DFTM outbreaks. Results from this case study should be interpreted, however, with caution. The actual defoliation history of the sample trees used for the heavy defoliation class was unknown. Sample trees were adjacent to an area of known heavy defoliation, but DFTM population centers and severe tree damage usually occur in clumps. Individual tree defoliation of 50 percent or less rarely results in significant mortality but does cause measurable growth reductions (Koerber and Wickman 1970; Wickman 1963, 1978b; Wickman and others 1980). There were only a few snags or downed dead trees in the sample area so defoliation could have been moderate rather than heavy, based on the 50-percent radial growth reduction found in the sample trees (table 1). Moderate defoliation would result in light subsequent tree mortality and, perhaps, little stand thinning.

Another difference between the Mammoth Lakes and Hell's Mountain case studies relates to growing site. The stands at Mammoth Lakes are on dry sites, with lower fir volumes, and they receive on the average about 50 cm less annual precipitation than do those at Hell's Mountain (Wickman 1963). The only other area where long-term studies indicate increasing radial growth of white fir after a severe outbreak is also on a dry site in northern California (Wickman 1978a). Except for the very ridgetop, the site index at Hell's Mountain is mostly class II. The "thinning effect" that enhances growth response may only occur on poor, dry sites. On good growing sites neither growth reduction nor recovery may be as extreme because the competition for nutrients and moisture is not as keen. Evidence of an older outbreak in the Hell's Mountain area may shed further light on this difference.

Eleven white fir were old enough to show patterns of tree growth between 1906 and 1912 that are very similar to growth patterns of the 1954-56 outbreak (fig. 2).

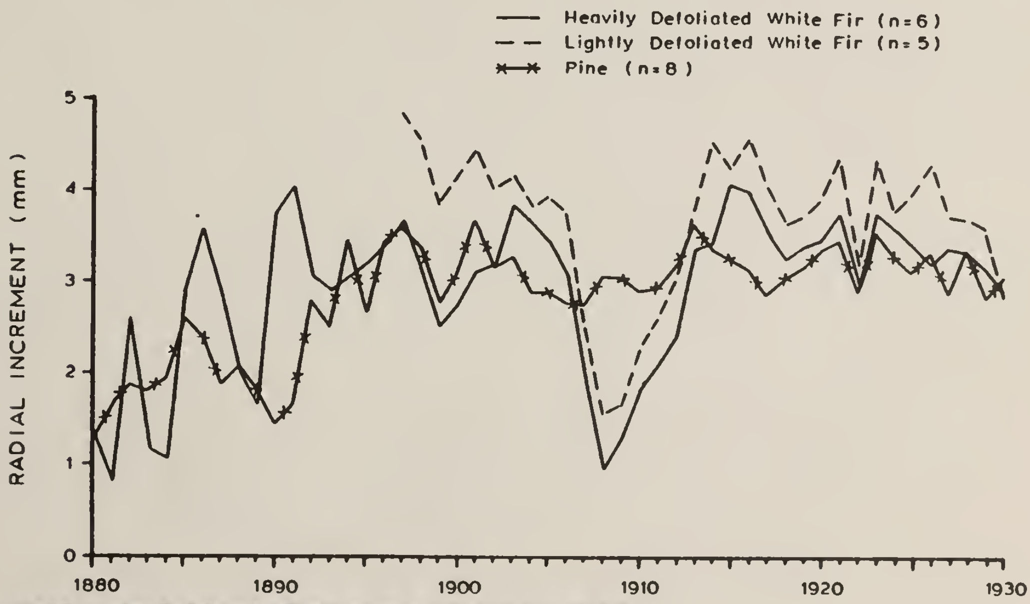

Figure 2.—Average annual radial growth of white fir and pine at Hell's Mountain Douglas-fir tussock moth area, 1880 to 1929.

A characteristic tree ring pattern has been noted for all other DFTM outbreaks studied (Brubaker 1978; Brubaker and Greene 1978; Koerber and Wickman 1970; Wickman 1963, 1978a, 1980; Wickman and others 1980). Furthermore, pine growth during 1907-9 was higher than fir growth and increasing rather than decreasing as one would expect from moisture deficiencies. Lending additional credence to a 1906-8 outbreak is the fact that in 1906 the first recorded California outbreak was underway at Fish Camp, California, about 72 km south (Eaton and Struble 1957). Precipitation and pine growth in northern California were above normal during this period (Keen 1937), and precipitation and tree growth at Mammoth Lakes were also on an upward trend (Wickman 1980); the growth reduction of white fir was apparently not the result of environmental factors but of a DFTM outbreak.

I have examined cores from mature white fir at the sites of old and recent DFTM infestations in the Inyo, Stanislaus, Eldorado, and Modoc National Forests without finding evidence of infestations other than those recorded by entomologists since 1936. This is not unusual because severe defoliation would have occurred on small acreages, or even within clumps of trees, and the probability of sampling those small units at a later date is slight. Brubaker (1978) reports from Idaho studies that breast height increment cores can identify severe DFTM infestations, but growth effects of moderate defoliation could not be reliably confirmed by dendrochronology techniques thus making it difficult to identify old outbreaks. Moderate and sometimes light defoliation were readily identified from increment cores taken after infestations in California and Oregon (Wickman 1963, Wickman and others 1980). This new evidence points to the 1906-8 outbreak as the earliest one detected from dendrochronologies in California.

The study site was most likely the locale of two DFTM outbreaks in a 50-year span. Because noticeable outbreaks (20 percent or greater tree defoliation) have not recurred on the same areas since 1936 (other than three at Iron Mountain in the Eldorado National Forest (Mason and others 1983)), the two outbreaks at Hell's Mountain in this century are unique. The stand dynamics at Hell's Mountain have also been influenced by the two DFTM defoliation episodes. Age distribution and site quality of mixed conifer stands on the west side of the Sierra Nevada are complex, highly variable, and often the result of past disturbances (Dolph and Amidon 1979). Two defoliation episodes probably increased nutrient cycling immediately after both outbreaks (Klock and Wickman 1978). This in turn may have had some longer term effects on site quality.

Age distribution is also affected by DFTM outbreaks. During the 1956 infestation, for example, there was heavier mortality in small understory white fir. Over 50 percent of the saplings and small poles were killed, mostly as a result of defoliation alone at the Hell's Mountain site (Wickman 1963). The growth patterns reported here do not, however, show a competitive advantage for pine growth after either outbreak as reported after the Mammoth Lakes outbreak (Wickman 1980), or as predicted from a simulation model of DFTM and stand dynamics in Idaho by Moore and Hatch (1981).

The effects of pest outbreaks, especially defoliators, may be subtle, but they are an important consideration when determining site quality classifications and predicting tree growth (Mattson and Addy 1975). Dendrochronologies of old outbreaks can have considerable value for estimating growth loss due to pests in future stand prognosis models. The data base for such measurements is small, unfortunately, and the case studies reported to date show considerable variation in

growth response after defoliation. Some of this variation may be the result of poor historical data or it may be caused by variation of site index and age distribution in individual areas (Dolph and Amidon 1979).

A concerted effort therefore should be made to protect the few remaining study areas that contain good historical records of past DFTM defoliation and tree damage. Determining long-term effects of defoliation on stand dynamics in these areas is the only way to document growth loss caused by forest pests, to validate stand prognosis models, and to compute benefit-cost analyses of proposed management practices.

English Equivalents

1 centimeter (cm) = 0.39 inch
1 meter (m) = 3.28 feet
1 kilometer (km) = 0.6214 mile
1 hectare (ha) = 2.47 acres

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